



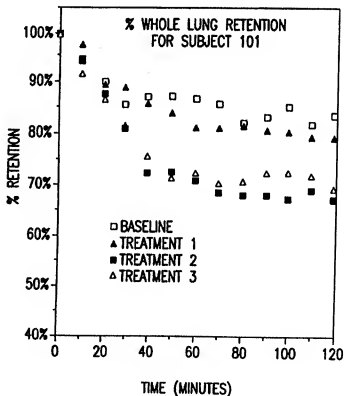
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : <b>A61K 31/70</b>		(11) International Publication Number: <b>WO 98/19685</b>
A1		(43) International Publication Date: 14 May 1998 (14.05.98)
(21) International Application Number: PCT/US97/18766		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).
(22) International Filing Date: 21 October 1997 (21.10.97)		
(30) Priority Data: 08/744,367 7 November 1996 (07.11.96) US		
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(54) Title: METHOD OF TREATING BRONCHITIS WITH URIDINE TRIPHOSPHATES AND RELATED COMPOUNDS

## (57) Abstract

A method of promoting clearance of retained mucous secretions in the bronchi, bronchioles and small terminal airways of a subject in need of such treatment is disclosed. The method comprises administering to the bronchi of the subject a uridine phosphate such as uridine 5'-triphosphate (UTP), or  $P_i$ - $P_{ii}$ -di(uridine-5') tetraphosphate ( $U_2P_4$ ), an analog of UTP, or any other analog, in an amount effective to promote mucociliary clearance and/or cough clearance of retained fluid in the bronchi, bronchioles and small terminal airways. Methods of administering the same would include; aerosol inhalation, any liquid suspension (including nasal drops or spray), oral form (liquid or pill), injected, intra-operative instillation or suppository form.



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METHOD OF TREATING BRONCHITIS WITH URIDINE  
TRIPHOSPHATES AND RELATED COMPOUNDS

INTRODUCTION

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This application is a continuation-in-part application of U.S. Application Serial No. 08/744,3673, filed November 7, 1996, which is incorporated herein by reference.

Technical Field

10 This invention relates to a method of removing retained mucous secretions from the bronchi, bronchioles and small terminal airways of a subject by administering uridine triphosphate and other purinergic receptor agonists.

Background of the Invention

Chronic bronchitis (CB) is excessive production of mucus in the bronchi  
15 accompanied by a recurrent cough that persists for at least three months of the year during at least two successive years. CB is the major non-asthmatic disease of the lung. This condition affects approximately 14 million Americans and is a major cause of death in the United States. Many different factors initiate CB, including cigarette smoking, environmental pollution, chronic  
20 infections and various genetic abnormalities. Of these factors, cigarette smoking is the most prevalent. Pathological changes in the lung consist of: (1) hypertrophy and hyperplasia of mucus-secreting glands in the bronchi, (2) increase in goblet cells, (3) disappearance or damage of cilia, and (4) chronic inflammatory changes and narrowing of small airways. Often, a bacterial or  
25 viral infection is present. Excess amounts of mucus are found in the airways and sometimes may occlude small bronchioles. Eventually, there may be scarring of the bronchial wall. Coughing is stimulated by retained mucus which cannot be adequately removed due to decreased cilia and lessened

mucociliary clearance (K. Svartengen, et al., *Exp. Lung Res.* 22, 555-576 (1996)). It is important that bronchitis patients clear retained mucus through coughing, however, often coughing is ineffective in adequately removing these secretions because the bronchitis patient cannot inspire deeply enough to cause air to flow distal to retained secretions.

Current treatments for chronic bronchitis include antibiotic therapy, bronchodilators, anti-inflammatory agents and chest physiotherapy. These treatments are often palliative in nature rather than effective in treating and/or preventing the progression of this disease. While antibiotics are effective in treating exacerbations of bronchitis due to bacterial infections, the disadvantage of antibiotic therapy is that the patient may develop antibiotic resistance. There is increasing evidence that chronic bronchitis is caused by viral infections. The disadvantage of bronchodilators is that they sometimes have adverse cardiovascular side effects. As for anti-inflammatory agents, there is some controversy as to which stage in the progression of chronic bronchitis inflammation plays a role. None of these treatments have been successful in enhancing clearance of retained mucous secretions.

It is now known that nucleoside phosphates such as uridine 5'-triphosphate (UTP) and its analogs modulate components of the mucociliary clearance system. UTP has been shown to increase Cl<sup>-</sup> secretion, and hence water secretion, from airway epithelial cells in vitro (S. Mason, et al., *Br. J. Pharmacol.* 103, 1649-56 (1991); see also, U.S. Patent No. 5,292,498 to R. Boucher (applicant intends the disclosure of this and all other patent references and publications cited herein be incorporated herein by reference). UTP has also been shown to increase cilia beat frequency in human airway epithelial cells in vitro (D. Drutz, et al., *Drug Dev. Res.* 37(3), 185 (1996)). UTP and other

nucleotides have been shown to stimulate the release of surfactant phospholipids from type II alveolar cells (S. Rooney, et al., *Progr. Respir. Res.* 27, 84-91 (1994); L. Gobran, et al., *Am J. Physiol.* 267, L625-33 (1994)). These effects have been shown to be mediated through a P2 receptor. The applicants believe

5 that the release of surfactant or surface active molecules, caused as part of the treatment with UTP and related compounds, will improve compliance of the small airways and consequently improve gas exchange. Clinically, UTP has been shown to increase mucociliary lung clearance 2.5-fold in normal

10 volunteers without any significant side-effects (K. Olivier, et al., *Am J. Respir. Care Med.* 154, 217-23 (1996)). UTP has also been shown to significantly improve cough clearance in primary ciliary dyskinesia (PCD) patients relative to vehicle (saline) (P. Noone, et al., *Amer. J. Respir. And Crit. Care Med.* 153(4), A530 (1996)). Also, in a subset of these PCD patients, the rate of sputum

15 expectoration appeared to be increased with inhalation of UTP versus saline (unpublished data of applicants). Additionally, a French biotechnology company, Laboratories Synthelabo, has developed a pharmaceutical composition for treating nasal mucous fluid congestion under the trademark name rhinATP™ which uses adenosine triphosphate (ATP) as the active compound.

20 Because of UTP's demonstrated ability to increase hydration of mucous secretions, increase cilia beat frequency and improve mucociliary whole lung clearance of retained secretions, applicants were motivated to investigate whether UTP, its analogs and other purinergic receptor agonists could effectively treat acute and chronic bronchitis as defined herein.

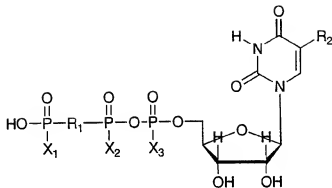
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### SUMMARY OF THE INVENTION

A method of treating bronchitis in a subject in need of such treatment is disclosed. Bronchitis is defined to include chronic bronchitis, acute bronchitis and bronchiectasis. Cough clearance is defined as induction of lung mucus  
5 clearance by cough. The method of the present invention comprises administering by inhalation an aerosol suspension of respirable particles to the bronchi, bronchioles and terminal small airways of the subject, the particles selected from the group consisting of general Formula I, i.e., uridine  
10 triphosphate [UTP] and its analogs, general Formula II, i.e.,  $P^iP^jU$  di(uridine-5') tetraphosphate [ $U_2P_4$ ] and its analogs, general Formula III, i.e., adenosine 5'-triphosphate [ATP] and its analogs, or general Formula IV, i.e., cytidine 5'-triphosphate [CTP] and its analogs, with the particles of Formula I, II, III or IV administered in an amount effective to hydrate retained bronchial mucous  
15 secretions and increase cilia beat frequency in the bronchi, bronchioles and terminal small airways of the subject, where by the retained mucous secretions are more easily transported from the bronchi, bronchioles and small terminal airways via mucociliary action.

UTP and its analogs are depicted in general Formula I:

## FORMULA I



wherein:

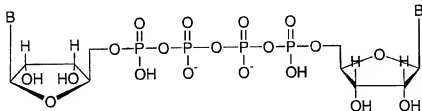
$X_1$ ,  $X_2$ , and  $X_3$  are each independently either O<sup>-</sup> or S<sup>-</sup>. Preferably,  $X_2$  and  $X_3$  are O<sup>-</sup>.

5  $R_1$  is O, imido, methylene, or dihalomethylene (e.g., dichloromethylene, difluoromethylene). Preferably,  $R_1$  is oxygen or difluoromethylene.

$R_2$  is H or Br. Preferably,  $R_2$  is H. Particularly preferred compounds of Formula I are uridine 5'-triphosphate [UTP] and uridine 5'-O-(3-thiotriphosphate) [UTPγS].

10 A dinucleotide is depicted by the general Formula II:

## FORMULA II

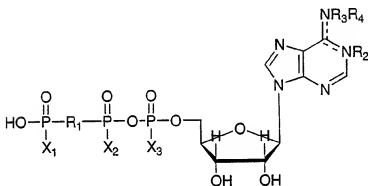


wherein:

B is uracil or adenine attached as shown in Formulae I and II.

ATP and its analogs are depicted by general Formula III:

### FORMULA III



5

wherein:

$R_1$ ,  $X_1$ ,  $X_2$ , and  $X_3$  are defined as in Formula I.

$R_3$  and  $R_4$  are H while  $R_2$  is nothing and there is a double bond between N-1 and C-6 (adenine), or

10  $R_3$  and  $R_4$  are H while  $R_2$  is O and there is a double bond between N-1 and C-6 (adenine1-oxide), or

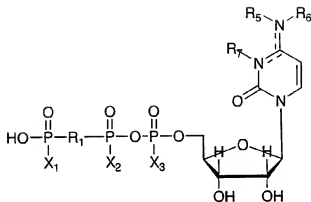
$R_3$ ,  $R_4$  and  $R_2$  taken together are  $-\text{CH}=\text{CH}-$ , forming a ring from N-6 to N-1 with a double bond between N-6 and C-6 (1, $N^6$ -ethenoadenine).

CTP and its analogs are depicted by general Formula IV:

15



## FORMULA IV



wherein:

$R_1$ ,  $X_1$ ,  $X_2$ , and  $X_3$  are defined as in Formula I.

$R_5$  and  $R_6$  are H while  $R_7$  is nothing and there is a double bond between

5 N-3 and C-4 (cytosine), or,

$R_5$ ,  $R_6$  and  $R_7$  taken together are  $-\text{CH}=\text{CH}-$ , forming a ring from N-3 to-N-4 with a double bond between N-4 and C-4 (3, $N^4$ -ethenocytosine).

For simplicity, Formulae I-IV herein illustrate the active compounds in the naturally occurring D-configuration, but the present invention also  
 10 encompasses compounds in the L-configuration, and mixtures of compounds in the D- and L- configurations, unless otherwise specified. The naturally occurring D-configuration is preferred.

A second aspect of the present invention is the use of UTP, or a compound of Formula II, III or IV, for the manufacture of a medicament for  
 15 carrying out a therapeutic method of treatment as given above.

A third aspect of the present invention is a pharmaceutical composition comprising UTP, or a compound of Formula II, III or IV, in a pharmaceutical carrier in an amount effective to hydrate mucous secretions in the bronchi,

bronchioles and small terminal airways; increase cilia beat frequency in the bronchi, bronchioles and small terminal airways; and enhance clearance of retained mucous secretions in the bronchi, bronchioles and small terminal airways.

5 DETAILED DESCRIPTION OF THE INVENTION

The method of the present invention may be used to remove mucous secretions retained in the mainstem bronchi and small airways of a subject for any reason, including (but not limited to) retention of secretions arising from airway diseases such as acute or chronic bronchitis, bronchiectasis, asthma and emphysema. The compound uridine triphosphate was identified as a potent agonist of the P2Y<sub>2</sub> purinergic receptor in human airway epithelial preparations. The novel feature of uridine triphosphate as compared to other treatments for bronchitis, such as antibiotics, bronchodilators and anti-inflammatory agents is that this compound promotes hydration, stimulation of mucociliary and/or cough to enhance the removal of retained bronchial secretions.

The present invention is concerned primarily with the treatment of human subjects, but may also be employed for the treatment of other mammalian subjects, such as dogs and cats, for veterinary purposes.

The term uridine triphosphate as used herein, include the pharmaceutically acceptable salts thereof, such as (but not limited to) an alkali metal salt such as sodium or potassium; an alkaline earth metal salt such as magnesium or calcium; or an ammonium or tetraalkyl ammonium salt, i.e.,  $\text{NH}_4^+$  (wherein X is  $\text{C}_{1-4}$  alkyl). Pharmaceutically acceptable salts are those that retain the desired biological activity of the parent compound and do not impart undesired toxicological effects.

The active compounds disclosed herein may be administered to the lungs of a patient by any suitable means, but are preferably administered by administering an aerosol suspension of respirable particles comprised of the active compound, which the subject inhales. The respirable particles may

5 liquid or solid. The quantity of the active compound included may be an amount sufficient to achieve dissolved concentrations of the active compound on the bronchial surfaces of the subject of from about  $10^{-7}$  to about  $10^{-1}$  Moles/liter, and more preferably from about  $10^{-4}$  to about  $5 \times 10^{-2}$  Moles/liter.

Depending upon the solubility of the particular formulation of active

10 compound administered, the daily dose to promote secretion drainage may be divided among one or several unit dose administrations. The total daily dose for UTP may range from about 6 to 720 milligrams of respirable uridine triphosphate for a human subject, depending upon the age and condition of the subject. A currently preferred unit dose for UTP is about 2 to 100 milligrams of

15 respirable uridine triphosphate particles given at a regimen of three to four administrations per day.

The liquid or solid particular uridine triphosphate prepared for practicing the present invention should include particles of respirable size: that is, particles of a size sufficiently small to pass through the mouth and larynx

20 upon inhalation and into the bronchi, bronchioles and terminal small airways of the lungs. In general, particles ranging from about 1 to 5 microns in size are considered respirable.

Some compounds of Formula I, III and IV can be made by methods which are well known to those skilled in the art; some are commercially

25 available, for example, from Sigma Chemical Company, PO Box 14508, St. Louis 63178. Compounds of Formula II can be made in accordance with

known procedures, or variations thereof which will be described by: E. Papaport, et al., *Proc. Natl. Acad. Sci. USA*, 72, 838-42 (1981); and K. Ng and L.E. Orgel, *Nucleic Acids Res.* 15(8), 3572-80 (1977).

In the manufacture of a formulation according to the invention, active  
5 agents or the physiologically acceptable salts thereof are typically admixed  
with, inter alia, an acceptable carrier. The carrier must be acceptable in that it is  
compatible with any other ingredients in the formulation and must not be  
deleterious to the patient. The carrier may be a solid or a liquid, or both. The  
formulations of the invention may incorporate one or more active compounds,  
10 and these formulations may be prepared by any of the well-known techniques  
of pharmacy consisting essentially of admixing the components.

Aerosols of liquid particles comprising the active compound may be  
produced by any suitable means, such as with a pressure-driven aerosol  
nebulizer or an ultrasonic nebulizer. See, e.g., U.S. Patent No. 4,501,729.  
15 Nebulizers are commercially available devices which transform solutions or  
suspensions of the active ingredient into a therapeutic aerosol mist either by  
means of acceleration of compressed gas, typically air or oxygen, through a  
narrow venturi orifice or by means of ultrasonic agitation. Suitable  
formulations for use in nebulizers consist of the active ingredient in a liquid  
20 carrier, the active ingredient comprising up to 40% w/w of the formulation,  
but preferably less than 20% w/w. The carrier is typically water (and most  
preferably sterile, pyrogen-free water) or a dilute aqueous alcoholic solution,  
preferably made isotonic with body fluids by the addition of, for example,  
sodium chloride. optional additives include preservatives if the formulation is  
25 not made sterile, for example, methyl hydroxybenzoate, antioxidants, flavoring  
agents, volatile oils, buffering agents and surfactants.

Aerosols of solid particles comprising the active compound may likewise be produced with any solid particulate medicament aerosol generator. Aerosol generators for administering solid particulate medicaments to a subject produce particles which are respirable, as explained above, and generate a

5 volume of aerosol containing a predetermined metered dose of a medicament at a rate suitable for human administration. one illustrative type of solid particulate aerosol generator is an insufflator. Suitable formulations for administration by insufflation include finely comminuted powders which may be delivered by means of an insufflator or taken into the nasal cavity in the

10 manner of a snuff. In the insufflator, the powder (e.g., a metered dose thereof effective to carry out the treatments described herein) is contained in capsules or cartridges, typically made of gelatin or plastic, which are either pierced or opened in situ and the powder delivered by air drawn through the device upon inhalation or by means of a manually-operated pump. The powder

15 employed in the insufflator consists either solely of the active ingredient or of a powder blend comprising the active ingredient, a suitable powder diluent, such as lactose, and an optional surfactant. The active ingredient typically comprises from 0.1 to 0.01 w/w of the formulation. A second type of illustrative aerosol generator comprises a metered dose inhaler. Metered dose

20 inhalers are pressurized aerosol dispensers, typically containing a suspension or solution formulation of the active ingredient in a liquefied propellant. During use these devices discharge a metered volume, typically from 10 to 150  $\mu$ l, to produce a fine particle spray containing the active ingredient. Suitable propellants include non-chlorofluorocarbon propellants as well as certain

25 chlorofluorocarbon compounds, for example, dichlorodifluoromethane, trichlorofluoromethane, dichlorotetrafluoroethane and mixtures thereof. The

formulation may additionally contain one or more cosolvents, for example, ethanol, surfactants, such as oleic acid or sorbitan trioleate, antioxidants and suitable flavoring agents.

Compositions containing respirable dry particles of micronized uridine triphosphate may be prepared by grinding the dry uridine triphosphate with a mortar and pestle, and then passing the micronized composition through a 400 mesh screen to break up or separate out large agglomerates. In dry powder delivery, the UTP may be formulated alone or in combination with diluent or carrier, such as sugars where the compounds may be intimately incorporated in the matrix through glassification or simply admixed with the carrier (i.e., lactose, sucrose, trehalose, mannitol) or other acceptable excipients for lung or airway delivery. The dry powder may be obtained by methods known in the art, such as spray-drying, milling, freeze-drying, etc.

The aerosol, whether formed from solid or liquid particles, may be produced by the aerosol generator at a rate of from about 10 to 150 liters per minute, more preferable from about 30 to 150 liters per minute, and most preferable about 60 liters per minute. Aerosols containing greater amounts of medicament may be administered more rapidly.

The particulate uridine triphosphate composition may optionally contain a dispersant which serves to facilitate the formation of an aerosol. A suitable dispersant is lactose, which may be blended with the uridine triphosphate in any suitable ratio (e.g., a 1 to 1 ratio by weight).

Another means of administering the active compound to the bronchi of the subject would involve administering a liquid/liquid suspension (either a nasal spray of respirable particles which the subject inhales, or nasal drops of a liquid formulation, or eye drops of a liquid formulation) comprised of the

active compound. Liquid pharmaceutical compositions of the active compound for producing a nasal spray or nasal or eye drops may be prepared by combining the active compound with a suitable vehicle, such as sterile pyrogen free water or sterile saline by techniques known to those skilled in the art.

Another means of administering the active compound would involve oral administration, in which pharmaceutical compositions containing compounds of Formula I, II, III or IV are in the form of tablets, lozenges, aqueous or oily suspensions, dispersible powders or granules, emulsion, hard or soft capsules, or syrups or elixirs. Compositions intended for oral use may be prepared according to any method known to the art for the manufacture of pharmaceutical compositions and such compositions may contain one or more agents selected from the group consisting of sweetening agents, flavoring agents, coloring agents and preserving agents in order to provide pharmaceutically elegant and palatable preparations. Tablets contain the active ingredient in admixture with nontoxic pharmaceutically acceptable excipients which are suitable for the manufacture of tablets. These excipients may be, for example, inert diluents, such as calcium carbonate, sodium carbonate, lactose, calcium phosphate or sodium phosphate; granulating and disintegrating agents, for example, corn starch, or alginic acid; binding agents, for example, starch, gelatin or acacia; and lubricating agents, for example magnesium stearate, stearic acid or talc. The tablets may be uncoated or they may be coated by known techniques to delay disintegration and absorption in the gastrointestinal tract and thereby provide a sustained action over a longer period. For example, a time delay material such as glyceryl monostearate or glyceryl distearate may be employed. Formulations for oral use may also be

presented as hard gelatin capsules wherein the active ingredient is mixed with an inert solid diluent, for example, calcium carbonate, calcium phosphate or kaolin, or as soft gelatin capsules wherein the active ingredient is mixed with water or an oil medium, for example, peanut oil, liquid paraffin or olive oil.

5        Another means of administering the active compound to the bronchi of the subject would involve a suppository form of the active compound, such that a therapeutically effective amount of the compound reaches the lung via systemic absorption and circulation.

Another means of administering the active compound would involve  
10    direct intra-operative instillation of a gel, cream, or liquid suspension form of a therapeutically effective amount of the active compound. Such intra-operative instillation could take place during bronchoscopy, thoracotomy or during surgery to remove non-functioning, hyper-inflated sections of the lung, as is sometimes required in advanced stages of bronchitis, bronchiectasis or  
15    emphysema

Those having skill in the art will recognize that the starting materials may be varied and additional steps employed to produce compounds encompassed by the present invention, as demonstrated by the following examples. In some cases protection of certain reactive functionalities may be  
20    necessary to achieve some of the above transformations. In general the need for such protecting groups will be apparent to those skilled in the art of organic synthesis as well as the conditions necessary to attach and remove such groups.

The invention is illustrated further by the following examples which are not to be construed as limiting the invention in scope or spirit to the specific  
25    procedures described in it.



EXPERIMENTALExample 1Tracheal Mucus Study in Sheep

The effects of UTP and  $U_2P_4$  on tracheal mucus velocity (TMV) were studied using the following procedures: The nasal passages of conscious adult ewes were anesthetized with a 2% lidocaine solution. After local anesthesia was produced, a modified endotracheal tube 7.5 mm was placed such that the cuff was just below the vocal cords (verified by fluoroscopy). Inspired air was warmed and humidified. The cuff of the endotracheal tube was inflated only during administration of the test compound to minimize possible impairment of TMV by the cuff. Test compounds were administered by nebulization in a volume of 4 mL over a period of 10-12 min.

TMV was measured by fluoroscopy. Ten to twenty radiopaque disks (Teflon®/bismuth trioxide; 1 mm diameter, 0.8 mm thick, weighing 1.8 mg) were introduced into the trachea through a modified suction catheter with a puff of compressed air (3-4 L/min). Velocities of the individual disks were recorded on videotape from a portable image intensifier unit. Individual disk velocities were calculated by measuring the distance traveled by each disk during a 1 min observation period. Values reported are the means of the individual disk velocities. A collar was worn by the sheep which was used as a standard to correct for magnification errors inherent in the fluoroscope.

Both UTP and  $U_2P_4$  produced significant dose-related effects on tracheal mucus velocity. The doses ranged from 4 to 400  $\mu$ mole. Both compounds had their maximal effects at a dose of 400  $\mu$ mole (4 ml of  $10^{-1}M$ ). UTP produced a maximal effect of  $125 \pm 7\%$  of baseline (mean  $\pm$  standard error,  $n = 6$ ).  $U_2P_4$  produced a maximal effect of  $144 \pm 9\%$  of baseline ( $n = 6$ ). Both compounds

produced their maximal effects 15 min after administration. The highest dose of UTP produced significant effects on TMV up to 4 h after administration. The effects of  $U_2P_4$  were significant out to 2 h after administration. Results are shown in Figures 1 - 3.

5

### Example 2

#### Mucociliary Clearance Study in Sheep

In this study healthy adult ewes were given  $^{99m}Tc$ -labeled human serum albumin ( $^{99m}Tc$ -HSA) via a nebulized aerosol. The  $^{99m}Tc$ -HSA (20mCi) was administered over 5 min through a nasotracheal tube introduced under local anesthesia with 2% lidocaine. After administration of the  $^{99m}Tc$ -HSA, the animals were given a test compound: either UTP or  $U_2P_4$ . Test compounds were administered by nebulization in a volume of 4 mL over a period of 10-12 min. The test compounds were given at a dose of 400  $\mu$ mole. After the administration of the test compound, the animals were extubated. Clearance of the radiolabeled particles was monitored with a gamma camera. Measurements were made at 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 76, 90, 105 and 120 min. Initial results ( $n = 7$ ) have shown that both test compounds promote clearance of the radiolabeled particles (compared to the saline control). Results are shown in Figure 4.

20

The results of the studies in sheep on tracheal mucus velocity (TMV) and whole lung mucociliary clearance (WLC) demonstrated that UTP and  $U_2P_4$  can enhance mucociliary clearance. UTP and  $U_2P_4$  were able to produce an enhancement of TMV. These data strongly suggest that UTP and  $U_2P_4$  enhance both TMV and mucociliary clearance, which is useful as shown in the clinical trials shown below (Example 4).

25

Example 3Treatment of a Human Subject with Mild Chronic Bronchitis

It has been demonstrated that two different doses of UTP given by inhalation (4ml of a liquid solution containing either 5 mg/ml or 25 mg/ml UTP) enhances mucociliary clearance over baseline (no inhaled treatment) and also over placebo, in a patient with mild chronic bronchitis. In this study, the patient inhaled the different doses of UTP and placebo on separate days. The procedure for measuring mucociliary clearance was accomplished by having the patient inhale, in the following order: technetium-labeled iron oxide particles and then either one of the two doses of UTP or placebo. After inhalation of the UTP or placebo, clearance of the radiolabel particles was measured by serial 2-minute gamma scintigraphy images for 2.5 hours. In order to establish baseline mucociliary clearance on the first day of the study, the patient inhaled only the radiolabel and then had the 2.5 hour gamma scintigraphy images performed. Safety data was collected by monitoring heart rate, ECG, blood pressure, oxyhemoglobin saturation by pulse oximetry prior to, during, and after inhalation for all dosing periods. During all phases of the study the patient in this study and the patients in the study described in Example 4 were monitored for any adverse reactions during each dosing period.

Figure 5 shows the Whole Lung Retention curves for baseline (no inhalation of UTP or placebo), both doses of UTP (5 mg/ml is labeled as "treatment 3", 25 mg/ml is labeled as "treatment 2"), and placebo (labeled as "treatment 1") over the 2.5 hour time period. A decline in retention demonstrates a clearance of the secretions in the lungs carrying the radiolabel

particles. In this case, both doses of UTP clearly enhance the clearance of secretions (mucociliary clearance) over placebo and baseline.

#### Example 4

##### 5                    Clinical Study in Patients with Chronic Bronchitis

This single-center study, conducted at a major academic center in the U.S., was a randomized, double-blind, cross-over evaluation of escalating, single inhaled doses of UTP in 26 adult patients with chronic bronchitis (CB). Patients enrolled in this study had to meet the American Thoracic Society  
10 definition of chronic bronchitis (excessive mucous production over 3 months of the year, for at least 2 successive years). Patients were included that had mild to moderate airflow obstruction (forced expiratory volume over 1 second > 65% of predicted at study entry). The majority of patients in this study were smokers; 14 patients were females and 12 were males. Five successive groups  
15 of five subjects (an additional patient was added in one cohort due to a drop-out) received a single dose of placebo and the appropriate dose of UTP (2.5, 5, 15, 25 and 45 mg/mL) in a randomized order. The dose of UTP and placebo were separated by at least 24 hours. The purpose of this study was to more carefully define the timecourse by which UTP enhances the expectoration of  
20 sputum in a patient with CB. This study also included evaluation of the numbers of specific cell types in the sputum (alveolar macrophages, ciliated epithelial cells, eosinophils, and neutrophils).

#### **- Treatment Assignments and Administration of Study Drug**

Each subject was randomly assigned to receive either 1) a single inhaled  
25 dose of placebo (normal saline) or 2) one of five doses of UTP, over two separate days. For dosing, each dose consisted of 4mL of 2.5, 5, 15, 25 or 45

mg/mL solution or placebo (normal saline) administered using a jet nebulizer (Pari LC PLUS™) powered by a portable compressor set at 14 L/min. Inhalation of placebo or UTP took approximately 8-15 minutes.

**- Efficacy Results**

- 5       The amount of sputum expectorated (weight in grams) was collected at baseline and at various time points post-dosing of UTP and placebo. The timepoints were: immediately to 5 minutes post-dosing, 6 minutes to 30 minutes post-dosing, and 31 minutes post-dosing to discharge (within several hours of post-dosing).
- 10       For the purposes of analysis, patients receiving placebo across all dose groups were combined (n=25); patients receiving UTP (all doses) were combined; and patients receiving the three highest dose levels (15, 25 and 45 mg/mL) [n=15] were combined. Figure 6 illustrates the effect of placebo versus UTP on the amount of sputum expectorated (weight in grams) at two
- 15       time points: baseline (spontaneous expectoration) versus immediately to 5 minute post-dosing. UTP (all doses combined) significantly enhanced the amount of sputum expectorated compared to baseline and placebo (all doses combined). The effect of UTP was even more pronounced when comparing the three highest dose levels of UTP (n=15) to the placebo group. The ability of
- 20       UTP to enhance the amount of sputum expectorated over placebo and baseline was also quite evident at the later timepoint of 6 - 30 minutes post-dosing, as shown in Figure 7. Figure 8 shows that at the 31 minute - discharge time period there was essentially no difference between the effect of UTP and placebo on the amount of sputum expectorated, indicating that the effect of
- 25       UTP is manifest over a short time, consistent with previous studies in other patient populations.

The cytology results from sputum samples collected at the 6-30 minute post-dosing time point are shown in Figures 9 (sputum containing alveolar macrophages) and Figure 10 (sputum containing respiratory ciliated epithelial cells). UTP (all doses combined) and UTP (three highest dose levels combined) significantly improved the percentage of patients producing a sputum sample containing alveolar macrophages (AM) compared to placebo (Figure 9). UTP (all doses combined) and UTP (three highest dose levels combined) also significantly improved the percentage of patients producing a sputum sample containing respiratory ciliated epithelial cells, when compared to placebo (Figure 10). It is noteworthy in Figure 10 that only 8% of the patients were able to produce a sample containing ciliated epithelial cells at baseline or after aerosolization of placebo; whereas, 73% of patients could produce such a sample in the UTP (3 highest dose level) group. These effects of UTP were also observed at the 0 to 5-minutes post-dosing timepoint for alveolar macrophages (UTP [all doses] = 32%; baseline/placebo = 8%/4%; UTP [3 highest doses] = 50%). The effects of UTP had returned to close to the baseline/placebo values at the 31-minute to discharge timeframe, consistent with the findings on sputum weight.

This study clearly demonstrates that aerosolized doses of UTP (particularly at the three highest dose levels of 15, 25 and 45 mg/mL) are more effective than placebo (normal saline) in enhancing the expectoration of sputum. Based on the types of cells present, it is clear that the sputum is produced from the deep lung, and is not simply secretions from the oropharynx. The effect of UTP to enhance the clearance of lung secretions (sputum) was manifest over a very short timeframe (within 30 minutes post-dosing), which is consistent with the effect seen in studies of UTP in normal

subjects (including smokers) and in one adult patient with CB on whole lung mucociliary clearance (Example 3).

In another study conducted in normal male smokers who did not have any lung obstruction (i.e., development of lung disease similar to chronic bronchitis from smoking), the subjects were given formulated UTP by inhalation aerosol three times a day for three consecutive days. The study was a randomized, placebo-controlled, crossover design (each subject received both UTP and placebo for 3 days each, separated by one week; order of treatment was randomly determined). Enhanced sputum production (and therefore mucociliary clearance) after inhalation of UTP versus placebo occurred within the same timeframe as described above (data not known).

In summary, data (Examples 1-4) from several pre-clinical (animal) and clinical (human) studies demonstrate that inhaled UTP significantly enhances whole lung mucociliary clearance as measured by gamma scintigraphy studies and as shown by enhanced removal of retained lung secretions (sputum expectoration). Clearance and removal of these retained secretions prevents complications and improves the health of patients with chronic bronchitis.

The subject methods and compounds described herein provide a means for treatment of bronchitis. The method comprises administering to the airways of the subject a uridine triphosphate such as uridine 5i-triphosphate (UTP) or any analog of UTP, for example,  $U_2P_4$ , in an amount effective to hydrate mucous secretions, to promote mucociliary and/or cough clearance, or to stimulate ciliary beat frequency and the release of surfactant or surface active molecules to promote improved compliance and gas exchange in the lungs.

The invention now being fully described, it will be apparent to one of ordinary skill in the art that many changes and modifications can be made thereto without departing from the spirit or scope of the appended claims.

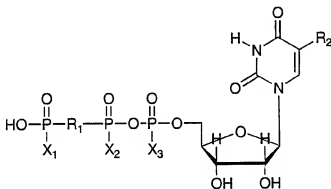


**WHAT IS CLAIMED IS:**

1. A method of treating bronchitis in a subject in need of such treatment, said method comprising:

- 5 administering to the subject a compound of Formula I, II, III or IV, or a pharmaceutically acceptable salt thereof, in a pharmaceutical carrier having an amount of said compound effective to hydrate bronchial mucous secretions or increase bronchial cilia beat frequency so that mucociliary clearance or cough clearance is enhanced:

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**FORMULA I**

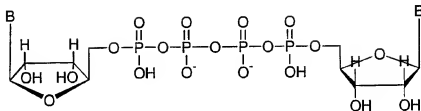
wherein:

$\text{X}_1$ ,  $\text{X}_2$ , and  $\text{X}_3$  are each independently selected from the group consisting of OH and SH;

- 15  $\text{R}_1$  is selected from the group consisting of O, imido, methylene, and dihalomethylene; and

$\text{R}_2$  is selected from the group consisting of H and Br;

## FORMULA II

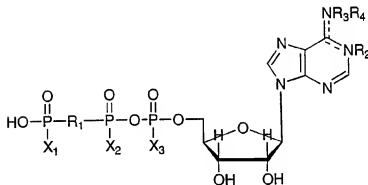


wherein:

B is uracil or adenine, attached as in Formulae I and III;

5

## FORMULA III



wherein:

$R_1$ ,  $X_1$ ,  $X_2$ , and  $X_3$  are defined as in Formula I,

$R_3$  and  $R_4$  are H while  $R_2$  is nothing and there is a double bond between

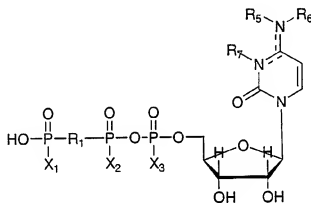
10 N-1 and C-6 (adenine), or

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$R_3$  and  $R_4$  and H while  $R_2$  is O and there is a double bond between N-1 and C-6 (adenine 1-oxide), or

$R_4$ ,  $R_5$  and  $R_2$  taken together are  $-\text{CH}=\text{CH}-$ , forming a ring from N-6 to N-1 with a double bond between N-6 and C-6 (1,  $\text{N}^6$ -ethenoadenine);

5

**FORMULA IV**

wherein:

$R_1$ ,  $X_1$ ,  $X_2$ , and  $X_3$  are defined as in Formula I,

$R_3$  and  $R_6$  and H while  $R_2$  is nothing and there is a double bond between N-3 and C-4 (cytosine), or,

$R_4$ ,  $R_5$  and  $R_2$  taken together are  $-\text{CH}=\text{CH}-$ , forming a ring from N-3 to N-4 with a double bond between N-4 and C-4 (3,  $\text{N}^4$ -ethenocytosine).

2. A method according to Claim 1, wherein said compound is delivered by administering a nebulized aerosol or suspension or solution of said compound to the nasopharyngeal airways of said subject, such that a therapeutically effective amount of said compound contacts the bronchi,

bronchioles and small terminal airways of said subject either directly or by systemic absorption and circulation.

3. A method according to Claim 1, wherein said compound is delivered by administering an oral form of said compound, such that a  
5 therapeutically effective amount of said compound contacts the bronchi, bronchioles and small terminal airways of said subject via systemic absorption and circulation.

4. A method according to Claim 1, wherein said compound is delivered by administering a liquid/liquid suspension, including eye drops of  
10 said compound to the eyes, or nasal drops, powder or spray, of said compound to the nasopharyngeal airways of said subject, such that a therapeutically effective amount of said compound contacts the bronchi, bronchioles and small terminal airways subject either directly or via systemic absorption and circulation.

- 15 5. A method according to Claim 1, where said compound is delivered by administering an injected form of said compound, such that at therapeutically effective amount of said compound contacts the bronchi, bronchioles and small terminal airways of said subject via systemic absorption and circulation.

- 20 6. A method according to Claim 1, wherein said compound is delivered by administering a suppository form of said compound, such that a therapeutically effective amount of said compound contacts the bronchi, bronchioles and small terminal airways of said subject via systemic absorption and circulation.

7. A method according to Claim 1, wherein said compound is delivered by administering an intra-operative instillation of a gel, cream, powder, foam, crystals or liquid suspension form of the active compound such that a therapeutically effective amount of said compound contacts the bronchi, bronchioles and small terminal airways of said subject via systemic absorption and circulation.

8. A method according to Claim 1, wherein said compound is administered in an amount sufficient to achieve concentrations thereof on the surfaces of the bronchi, bronchioles and small terminal airways of said subject of from about  $10^{-7}$  to about  $10^{-4}$  moles/liter.

9. A method according to Claim 1, wherein  $X_2$  and  $X_3$  are OH.

10. A method according to Claim 1, where  $R_1$  is oxygen.

11. A method according to Claim 1, wherein  $R_2$  is H.

12. A method according to Claim 1, wherein said compound of Formula I is selected from the group consisting of uridine 5'-triphosphate, uridine 5'-triphosphate, uridine 5'-O-(3-thiotriphosphate), 5-bromouridine 5'-triphosphate and the pharmaceutically acceptable salts thereof.

13. A method according to Claim 1, wherein said compound of Formula II is selected from the group consisting of  $P^i, P^i$ -di(uridine-5')tetraphosphate ( $U_2P_4$ ) and  $P^i, P^i$ -di(adenosine-5')tetraphosphate ( $A_2P_4$ ) and pharmaceutically acceptable salts thereof.

14. A method according to Claim 1, wherein said compounds of Formula III is selected from the group consisting of adenosine 5'-triphosphate, 1,N<sup>6</sup>-ethenoadenosine 5'-triphosphate, adenosine 1-oxide 5'-triphosphate and the pharmaceutically acceptable salts thereof.

5 15. A method according to Claim 1, wherein said compound of Formula IV is selected from the group consisting of cytidine 5'-triphosphate (CTP), 3,N<sup>4</sup>-ethenocytidine 5'-triphosphate and the pharmaceutically acceptable salts thereof.

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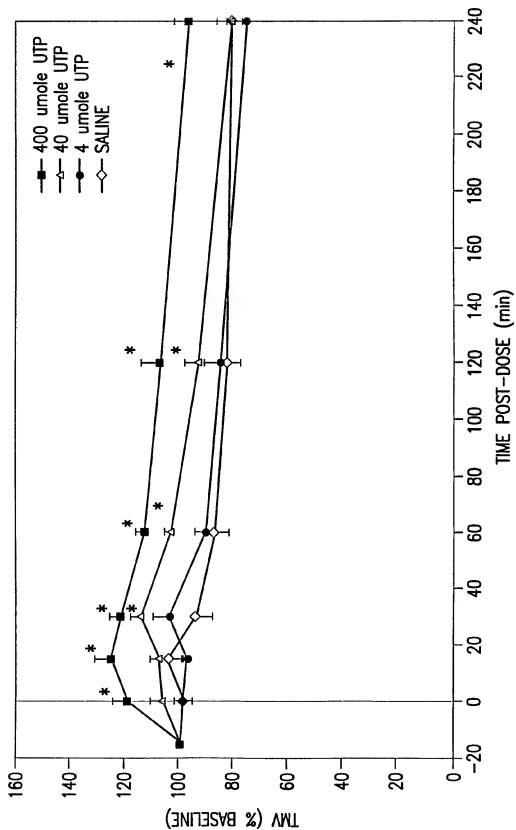
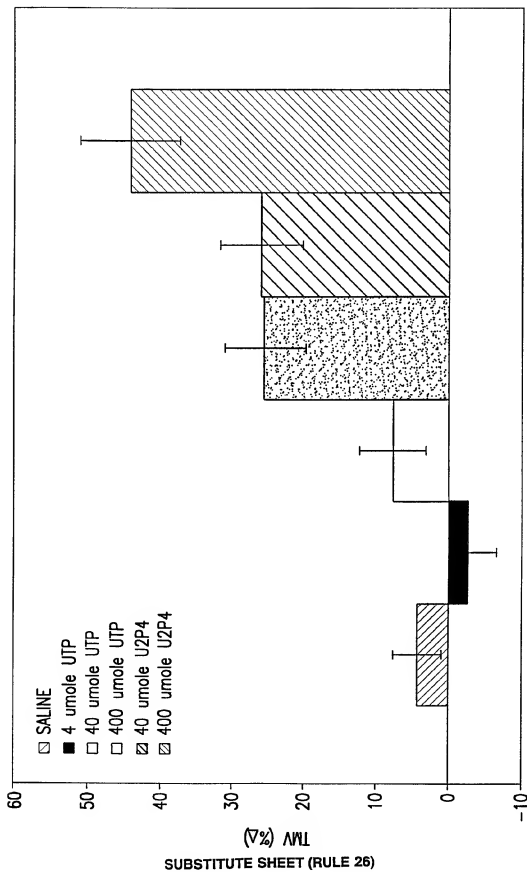


FIG.1

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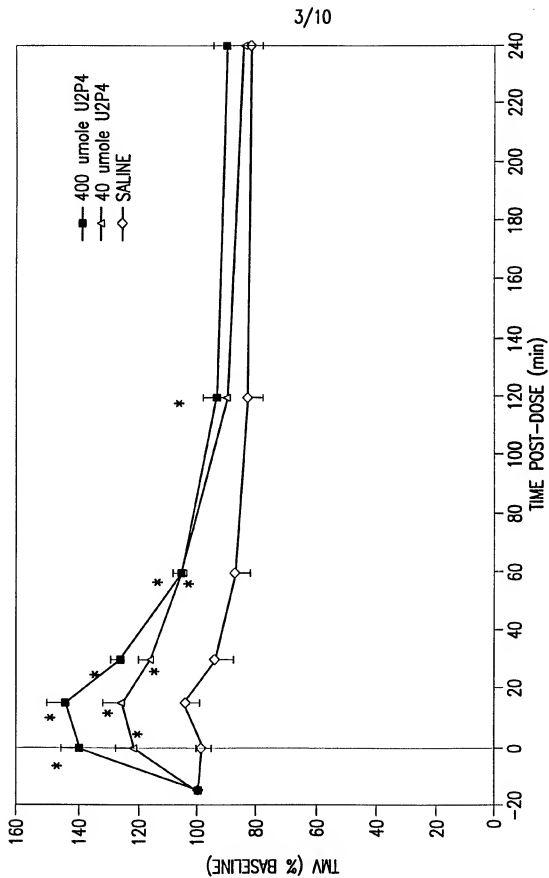


FIG.3

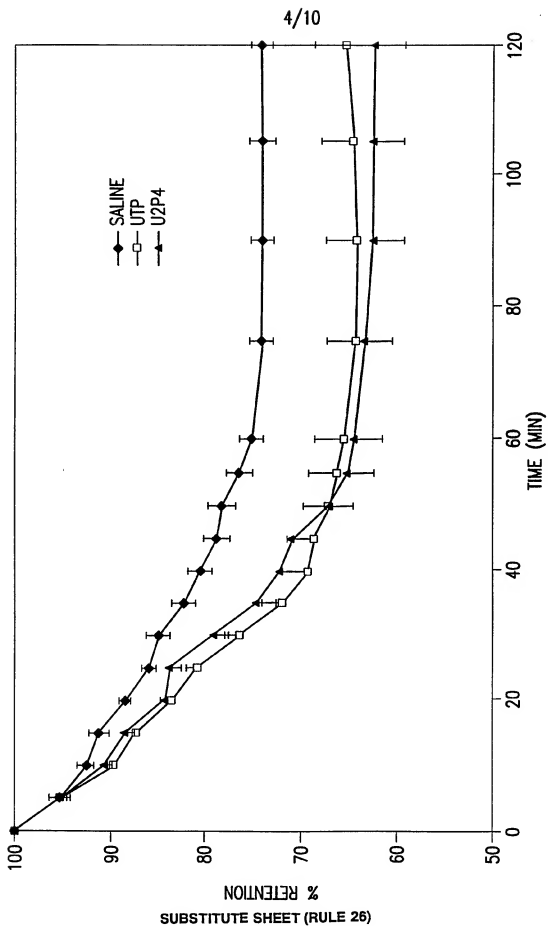


FIG. 4

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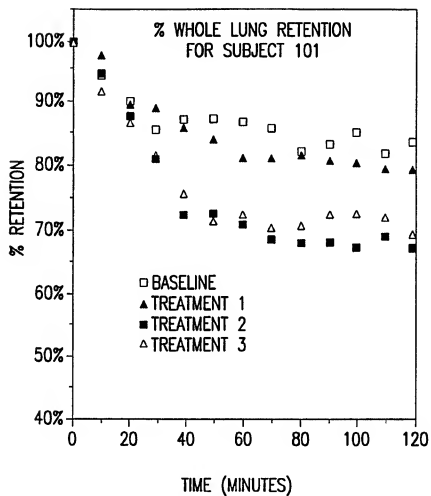


FIG.5

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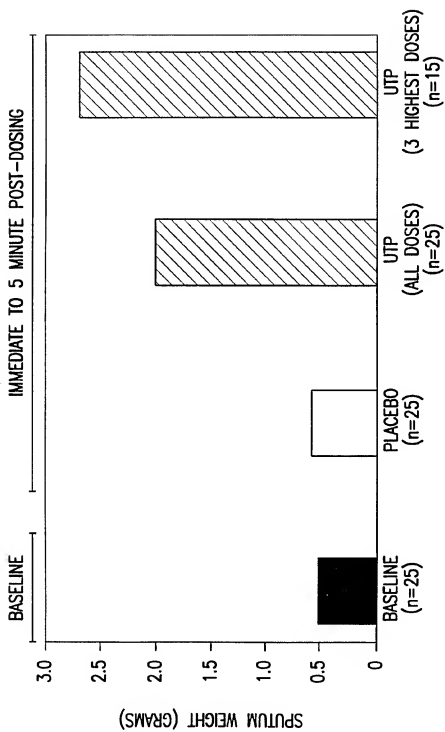


FIG.6

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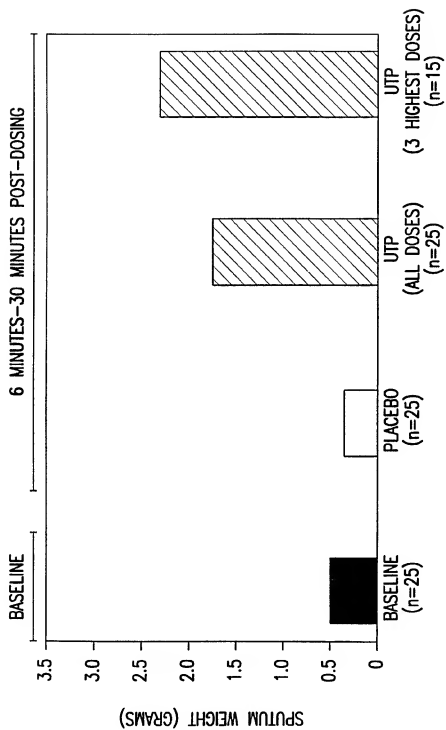


FIG. 7

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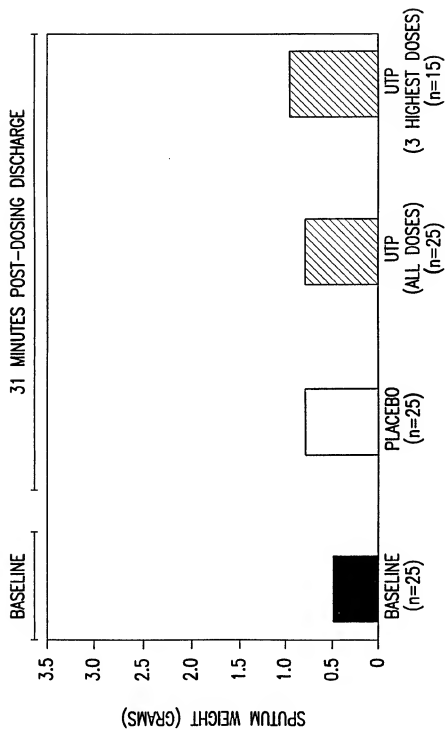


FIG.8

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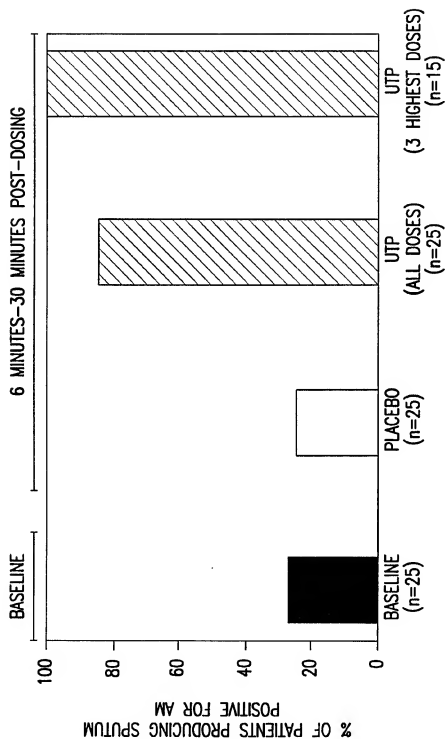


FIG.9

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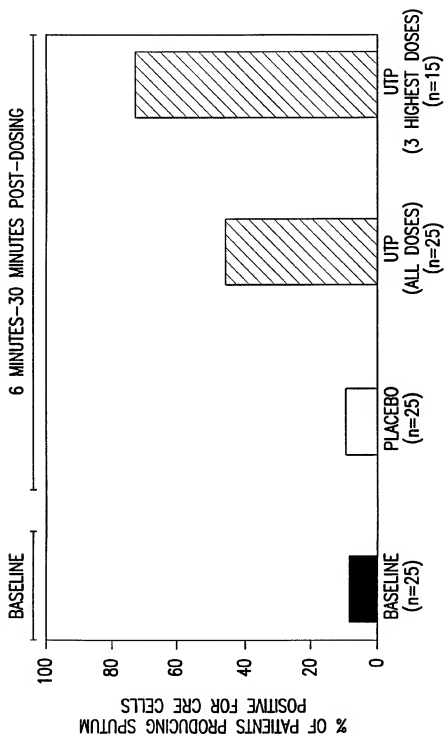


FIG.10



# INTERNATIONAL SEARCH REPORT

Int. l. Application No  
PCT/US 97/18766

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 6 A61K31/70

According to International Patent Classification(IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 6 A61K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 94 08593 A (UNIVERSITY OF NORTH CAROLINA) 28 April 1994 see the whole document ---	1,2,4,5, 9-15
X	WO 92 11016 A (FISONS PLC) 9 July 1992 see the whole document ---	1,2,4,5, 9-15
X	US 5 292 498 A (BOUCHER JR) 8 March 1994 see the whole document ---	1,2,4,5, 9-15
X	A.T. BASSIN ET AL.: "Prevention of ventilator-associated pneumonia." CLIN. CHEST MED., vol. 16, no. 1, 1995, pages 195-208, XP002046472 see the whole document ---	1
-/-		

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

### \* Special categories of cited documents:

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Date of the actual completion of the international search

Date of mailing of the international search report

18 February 1998

06/03/1998

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## INTERNATIONAL SEARCH REPORT

Int. Patent Application No.  
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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category <sup>1</sup>	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	R.E. WOOD ET AL.: "Recent advances in aerosol therapy." J. AEROSOL MED.: vol. 7, no. 1, 1994, pages 1-11, XP002046473 see page 4 - page 5 -----	1,2,4,5, 9-15
X	K.N. OLIVER ET AL: "Acute safety and effects on mucociliary clearance of aerosolized uridine 5'-triphosphate+/- amiloride in normal human adults." AM. J. RESPIR. CRIT. CARE MED., vol. 154, no. 1, 1996, pages 217-223, XP002056055 see the whole document -----	1,2,4, 8-12
P,X	WO 96 40059 A (UNIVERSITY OF NORTH CAROLINA) 19 December 1996 see the whole document -----	1,2,4, 8-10,13

# INTERNATIONAL SEARCH REPORT

information on patent family members

International Application No  
PCT/US 97/18766

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